

EPOXI

EPOXI/EPOCH Observations of Transiting Extrasolar Planets

Drake Deming
February 20, 2009



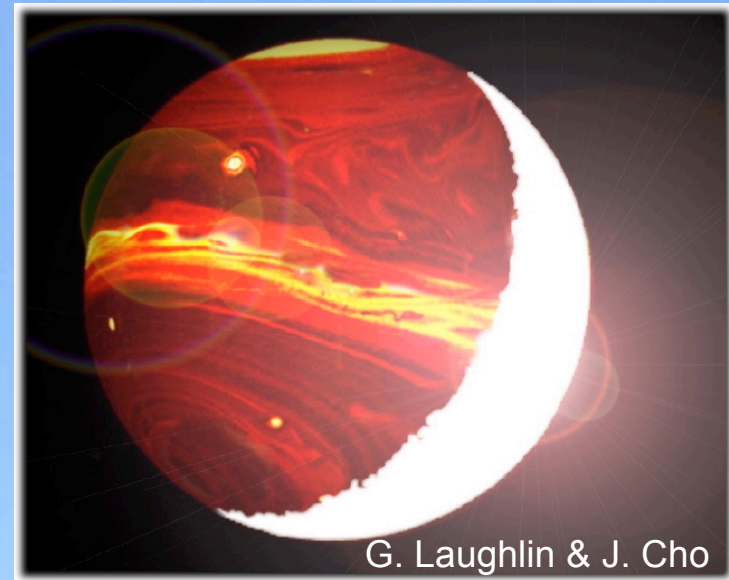
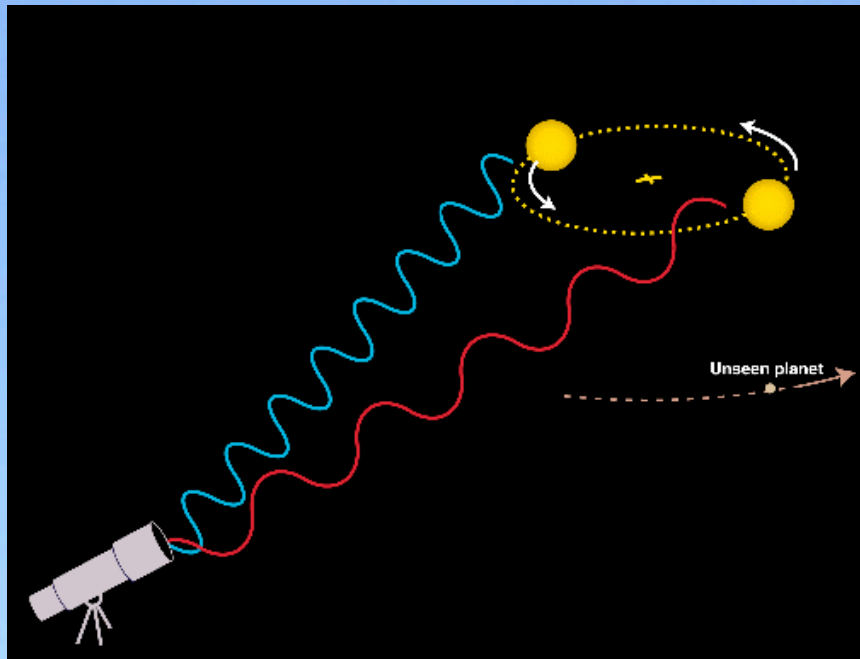
JPL



What I'm Going to Discuss.....

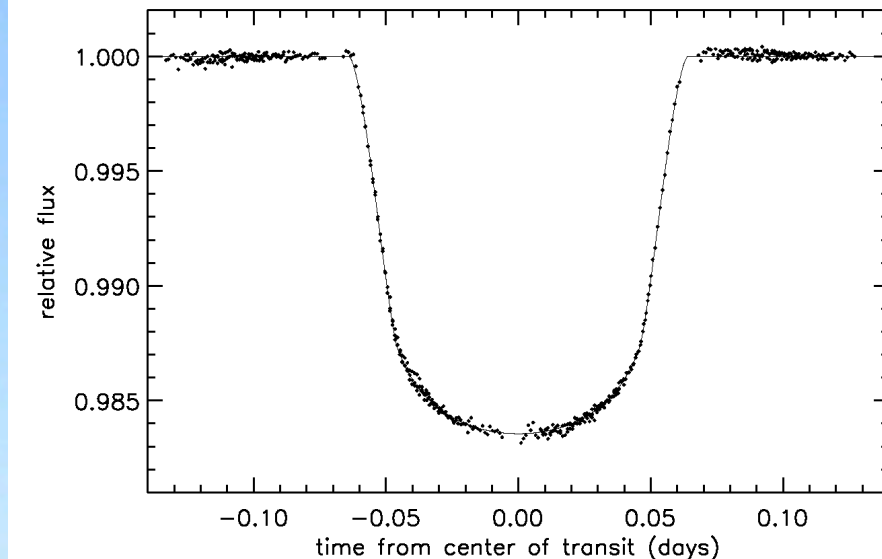
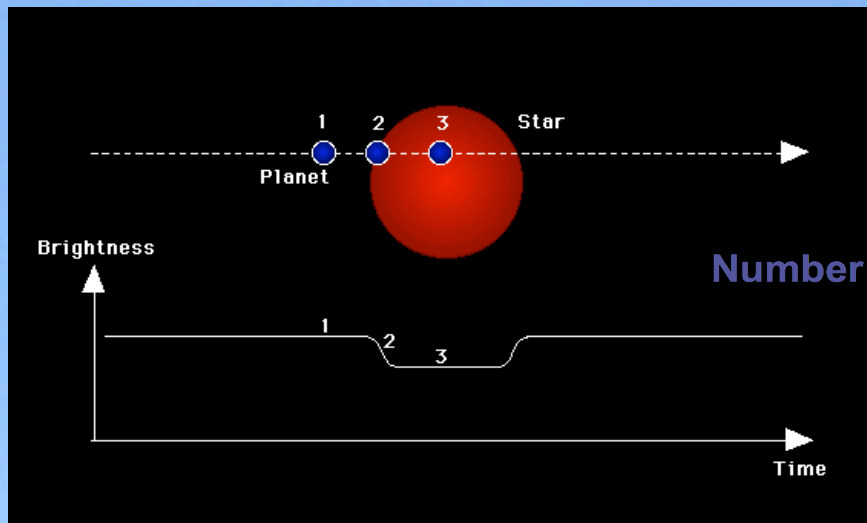
- ❑ Science value of transiting planets
- ❑ History of EPOXI - why the funny name
- ❑ Quality of our data, and what we will learn
- ❑ Earth-as-an-extrasolar-planet

Since 1995, more than 300 extrasolar planets have been discovered - most by radial velocity (indirect detection)

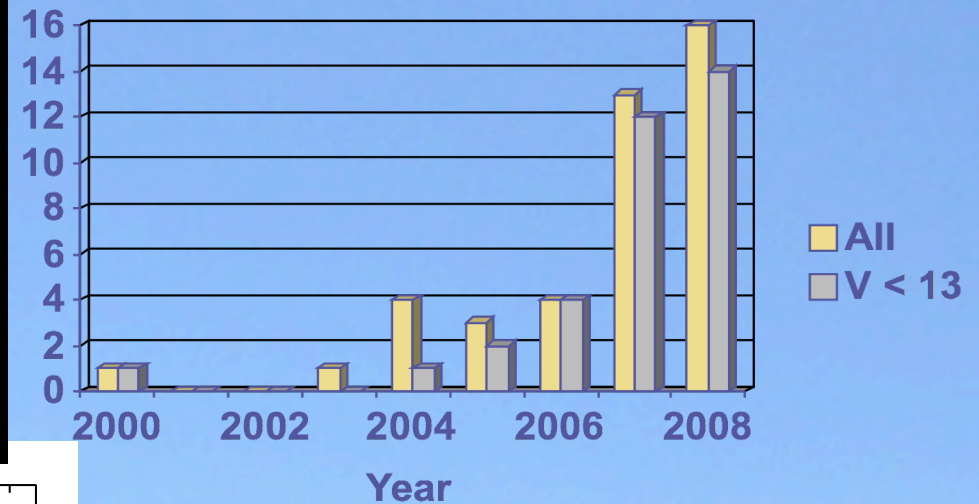


Many of these planets are close to their stars (0.05 AU) - the "hot Jupiters"

Close-in planets have a high probability to *transit*

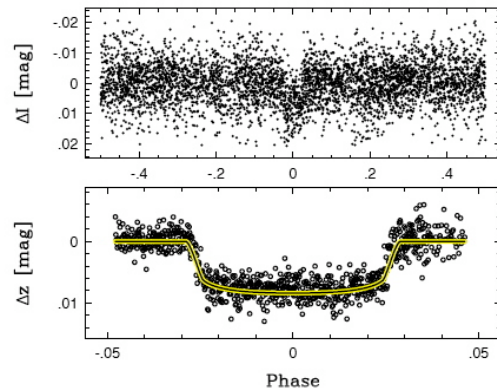


Transiting Planets Discovery Rate

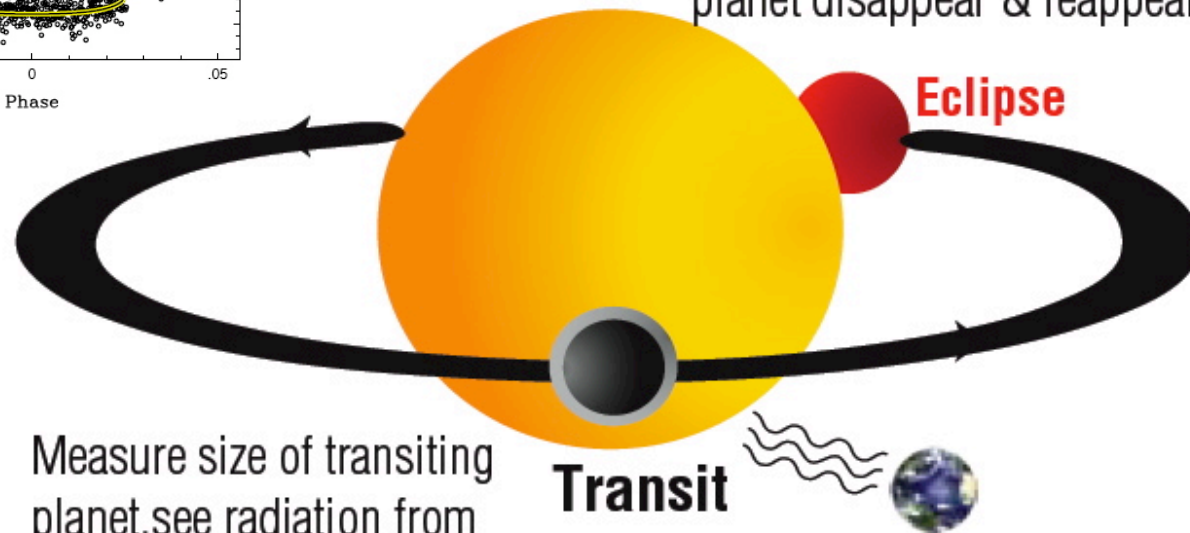


36 exoplanets are now known transiting bright solar-type stars & discovery rate is *accelerating*

Transit Science



See thermal radiation from planet disappear & reappear

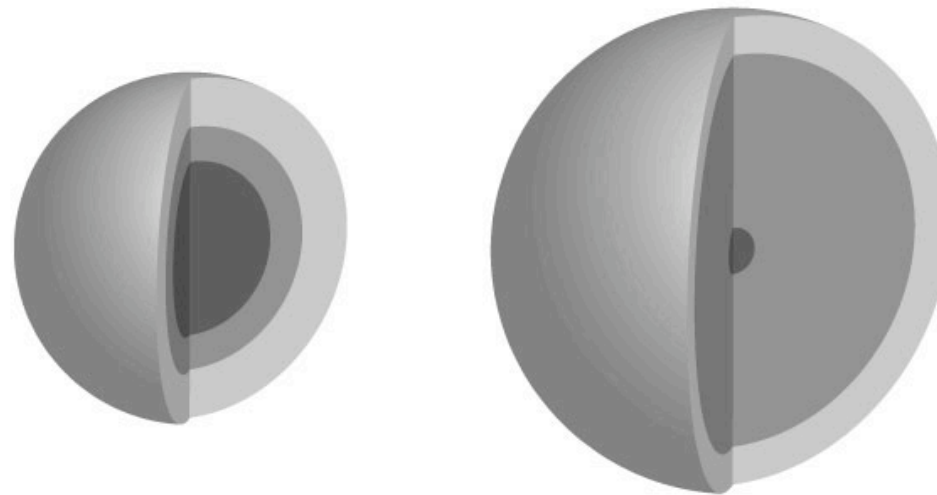


Measure size of transiting planet, see radiation from star transmitted through the planet's atmosphere

Gravitational tug of unseen planets alters transit times

TRA0009

Mass & Radius from transits inform us of the planet's average interior structure



HD 149026 b

Jupiter

- hydrogen and helium gas
- liquid metallic hydrogen
- heavy element core

History of EPOXI

- ❑ Deep Impact Prime mission impacted Comet Tempel-2 in July 2005, then the flyby spacecraft entered a storage orbit
- ❑ 2006 Discovery AO, solicited re-use as Mission-of-Opportunity. Selections included:
 - Extrasolar Planet Observations and Characterization (EPOCh, D. Deming et al.)
 - Use the CCD imager to acquire high-precision transit photometry
 - Known, bright, transiting systems (follow-up, not discovery)
 - Deep Impact eXtended Investigation (DIXI, M. A'Hearn et al.)
 - Selection Letters dictated a combined investigation for Step-2
 - EPOCh + DIXI = EPOXI.....voila!
 - EPOXI was confirmed for Step-2 in October 2007
 - "Nice acronym....." - Alan Stern

EPOCH Science Team

Drake Deming (GSFC), Principal Investigator
David Charbonneau (Harvard), Deputy P.I.

Sarah Ballard (CfA)

Nick Cowan (Univ. Wash)

Don Hampton (U. Alaska)

Matt Holman (SAO)

Carey Lisse (APL)

Vikki Meadows (U. Wash.)

Alfred Schultz (GSFC)

Joseph Veverka (Cornell)

Dennis Wellnitz (U. MD)

Richard Barry (GSFC)

Jessie Christiansen (CfA)

Tilak Hewagama (U. MD)

Marc Kuchner (GSFC)

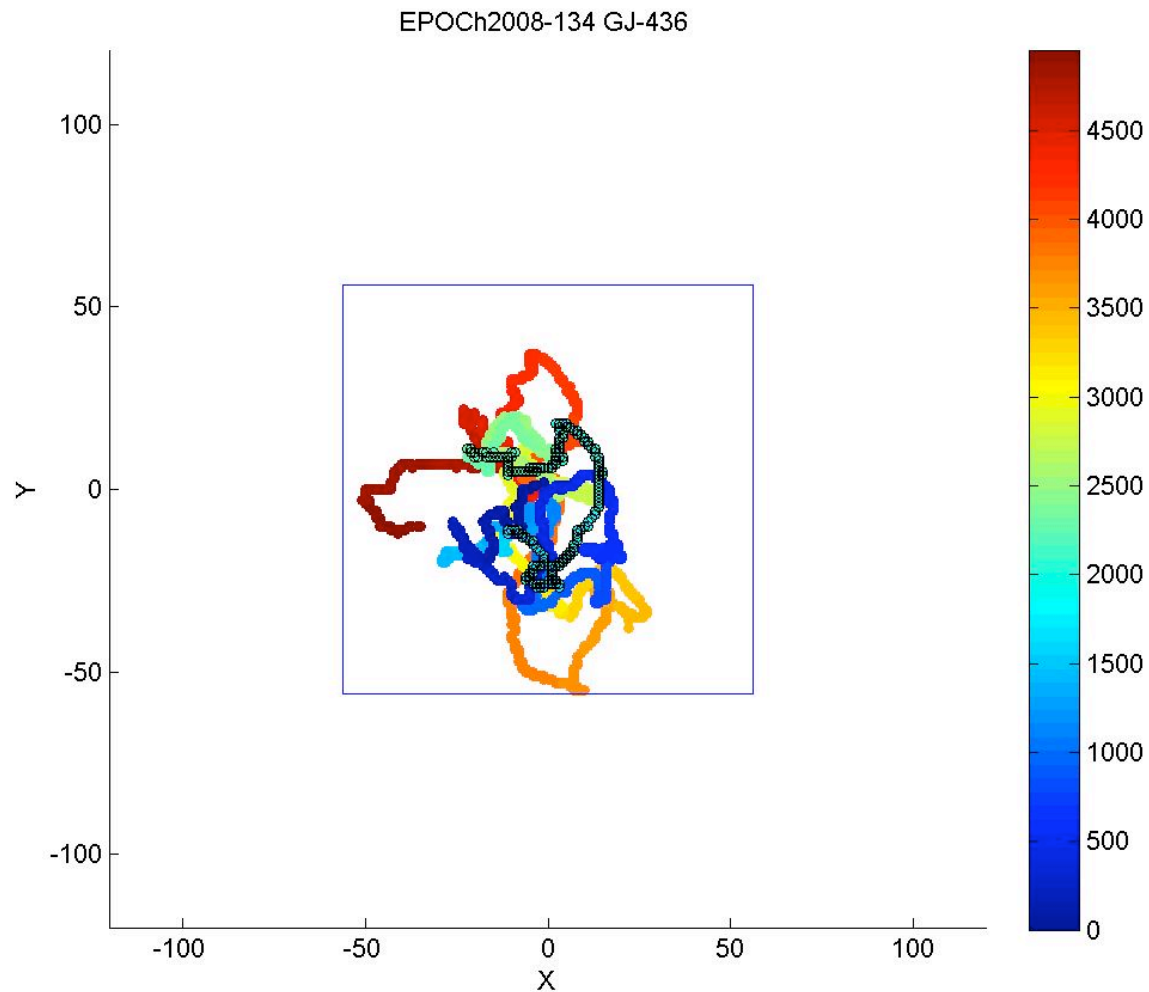
Timothy Livengood (NCESE)

Tyler Robinson (U. Wash)

Sara Seager (MIT)

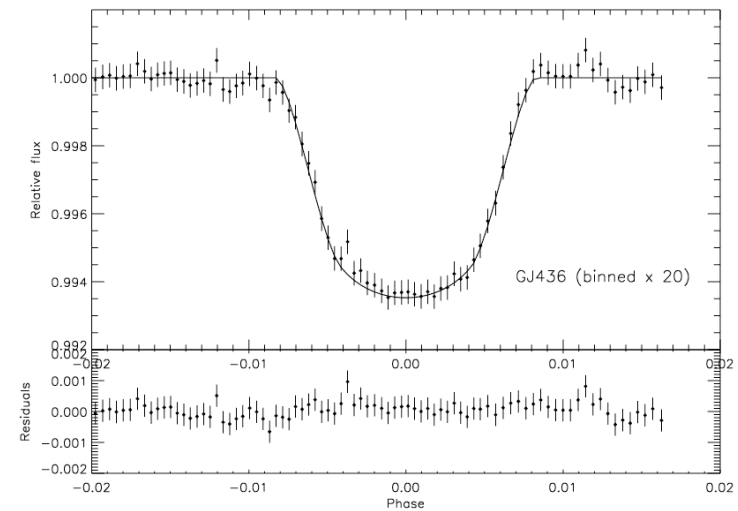
Spacecraft pointing (in)stability is our principal challenge

EPOXI



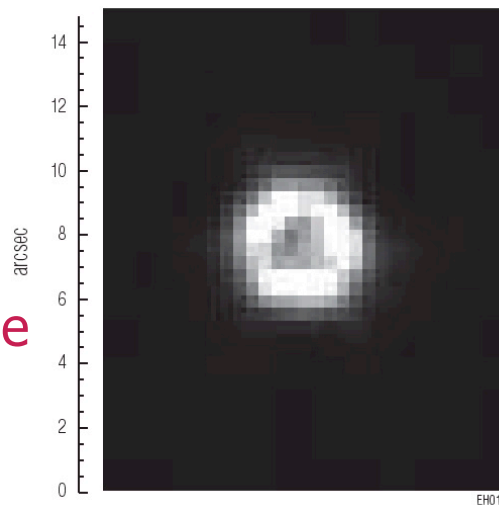
Why we need spaceborne data...

- ❑ For higher S/N photometry
 - improved radii for the giant planets
 - reflected light - or thermal emission
 - rings and moons
 - detection of even smaller planets
 - transit timing to \sim seconds precision
- ❑ Continuous coverage
 - discovery of smaller planets
 - Trojan planets?



EPOCH transit of a
Neptune-sized planet in
GJ 436

Capitalize the
defocus...!



Our targets... observed Jan-Aug, 2008 EPOXI in “follow-up mode”, unlike Kepler

EPOXI

☐ HAT-P-4

- a “puffed up” giant planet, $R \sim 1.3$ times Jupiter, $M \sim 0.7$ times Jupiter

☐ TrES-3

- a giant planet in a 31-hour orbit!
- potential for large reflected light signal (0.1%)!

☐ WASP-3

- a strongly heated giant planet - thermal emission in the visible?

☐ TrES-2

- a giant planet in the Kepler field... can combine with Kepler data

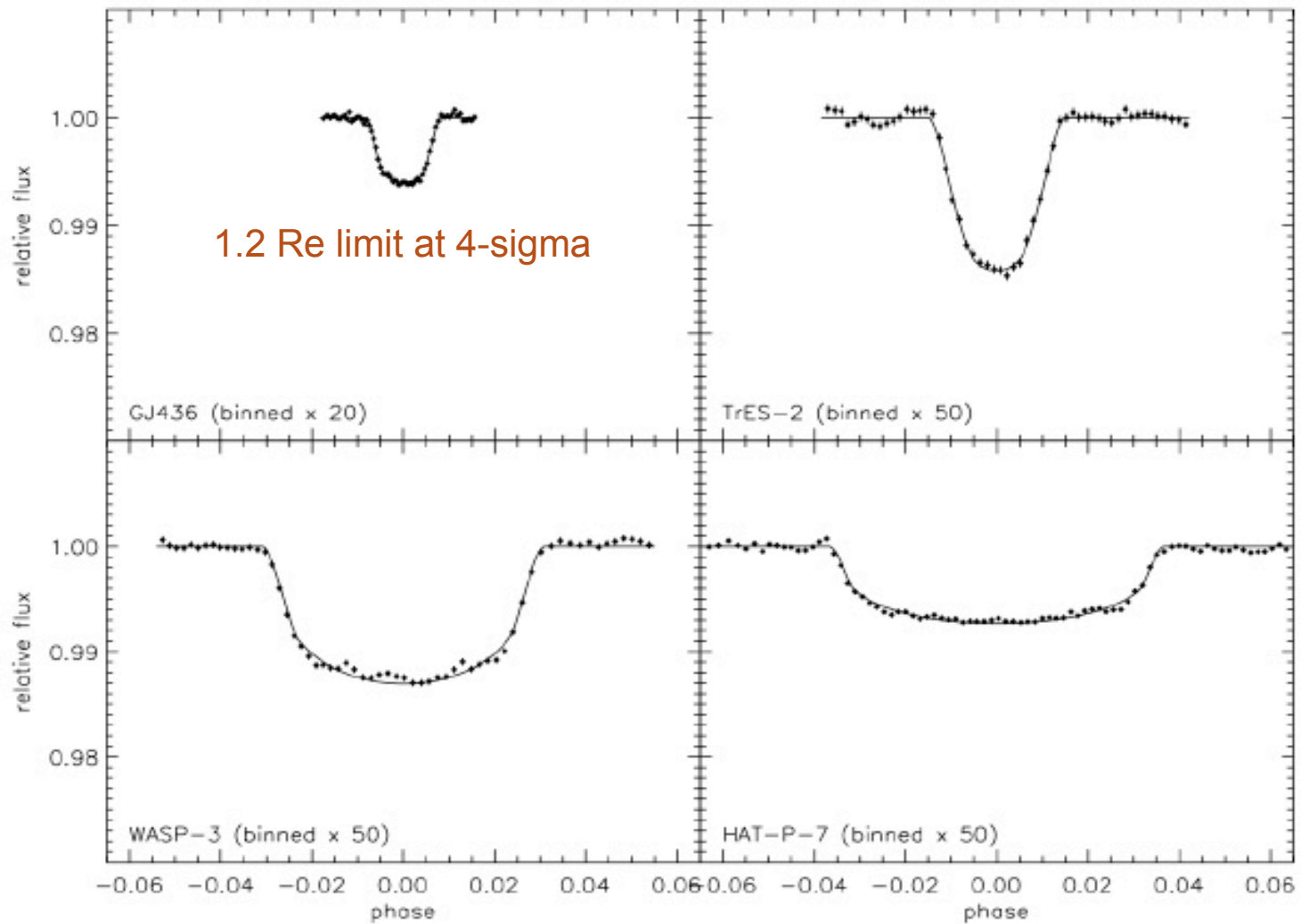
☐ HAT-P-7

- even more strongly heated than WASP-3; also in Kepler field

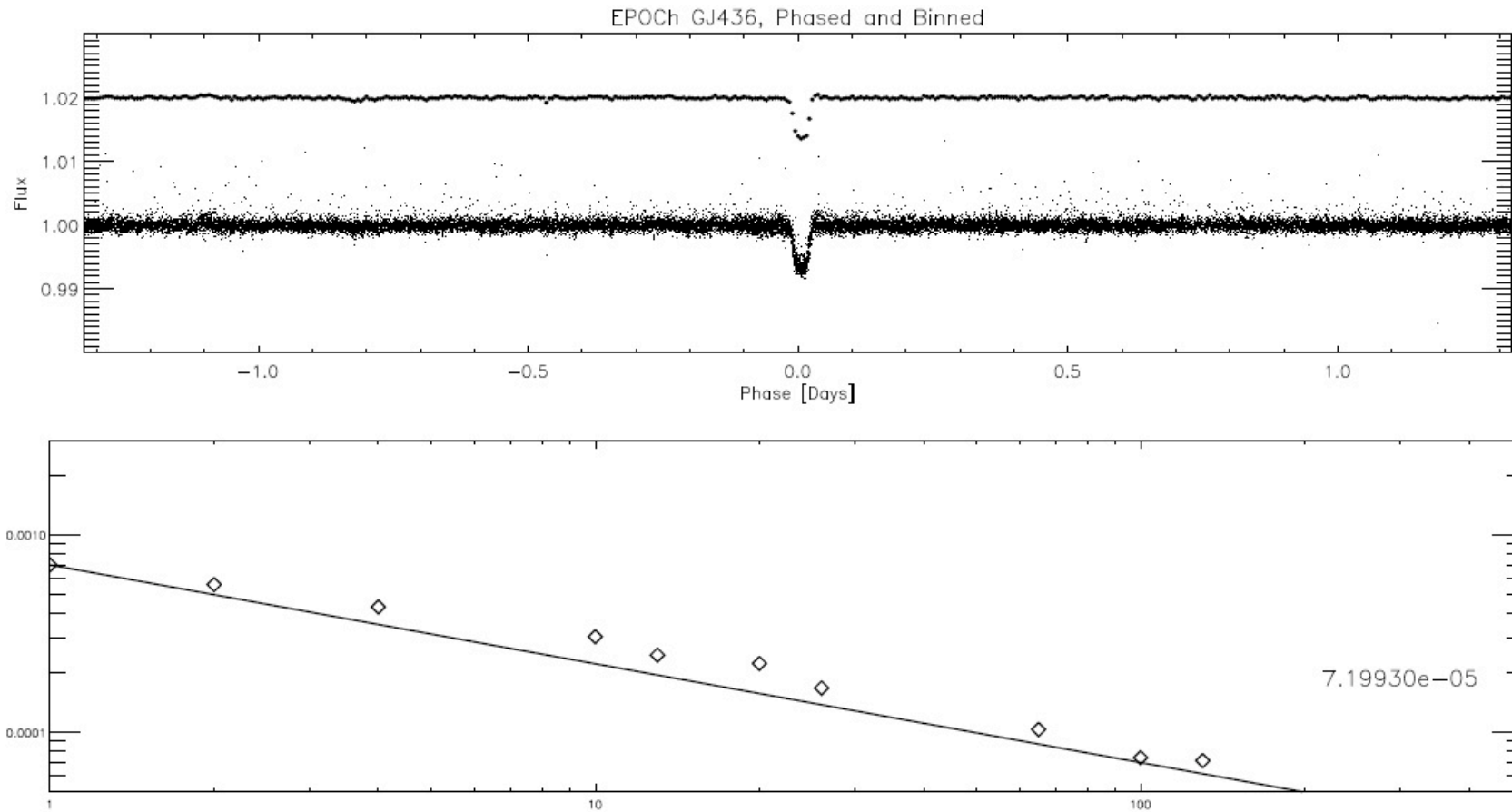
☐ GJ 436

- Smallest known transiting planet (Neptune-sized); M-dwarf star
- Super-earths are predicted! We covered out to the *habitable zone*!

Family portrait



Nearly photon-limited precision....



Search for an Earth-sized planet (in GJ436)

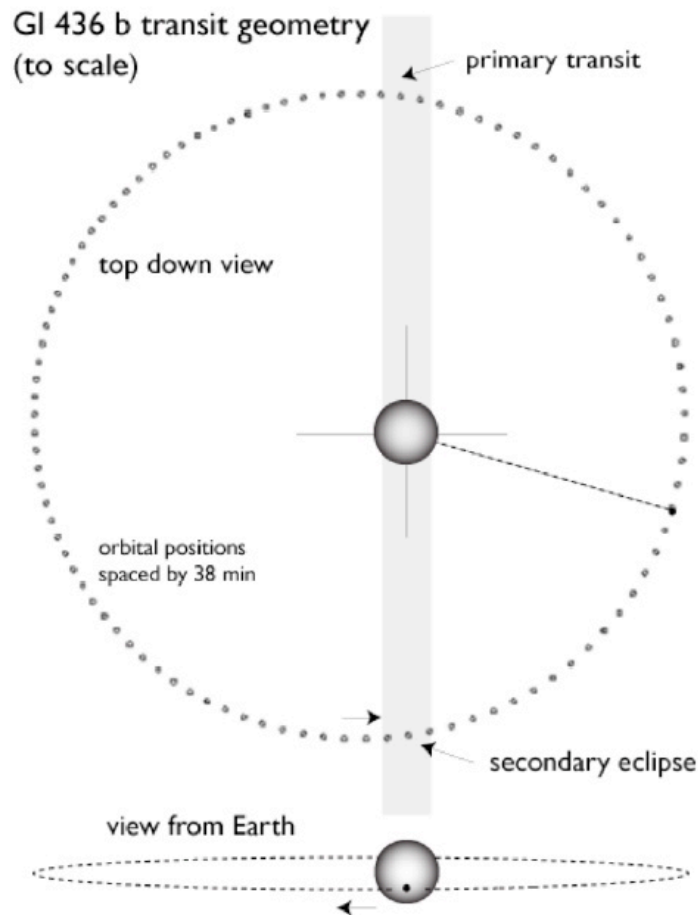


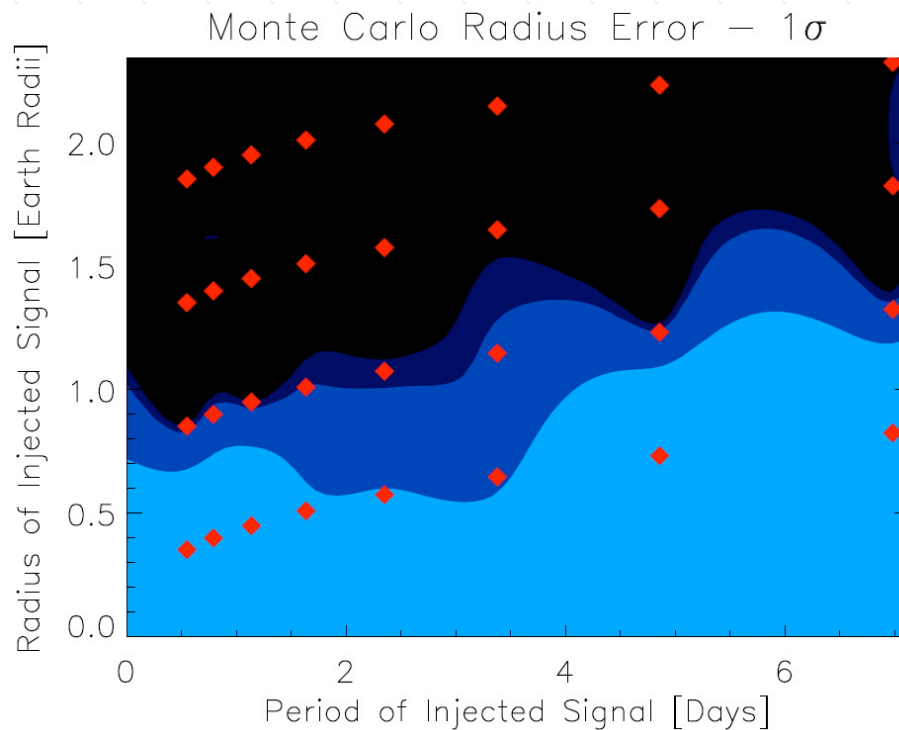
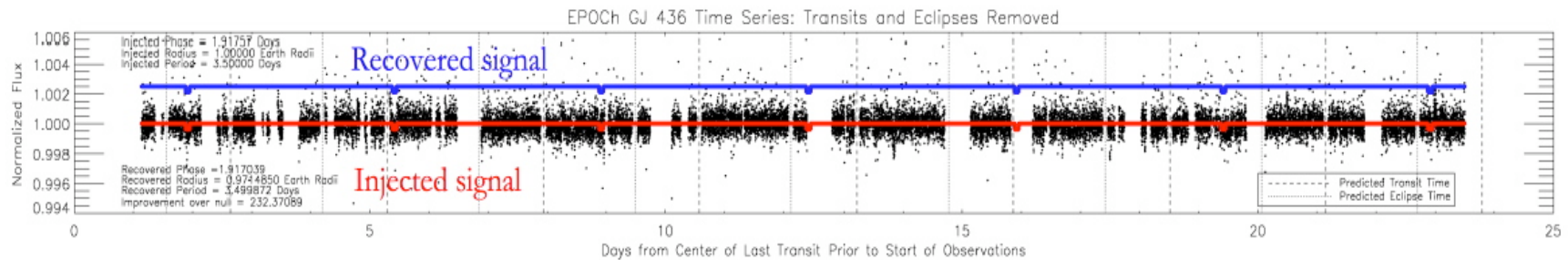
image credit: Greg Laughlin (oklo.org)

Eccentric orbit requires
perturbation by a second
planet ... so the theorists say

*If the second planet lies in
the same plane, it should
transit also....*

EPOXI observed the
system for 22 days...

Results of our search.....



Results show that no other planets transit, down to about 1.5 Earth radii

...how is e for GJ436b maintained?

EPOCH Earth Observations

Imaging in all HRI filters hourly, (some at 15 min cadence)
IR spectroscopy twice hourly

Study the Earth-as-an-exoplanet:

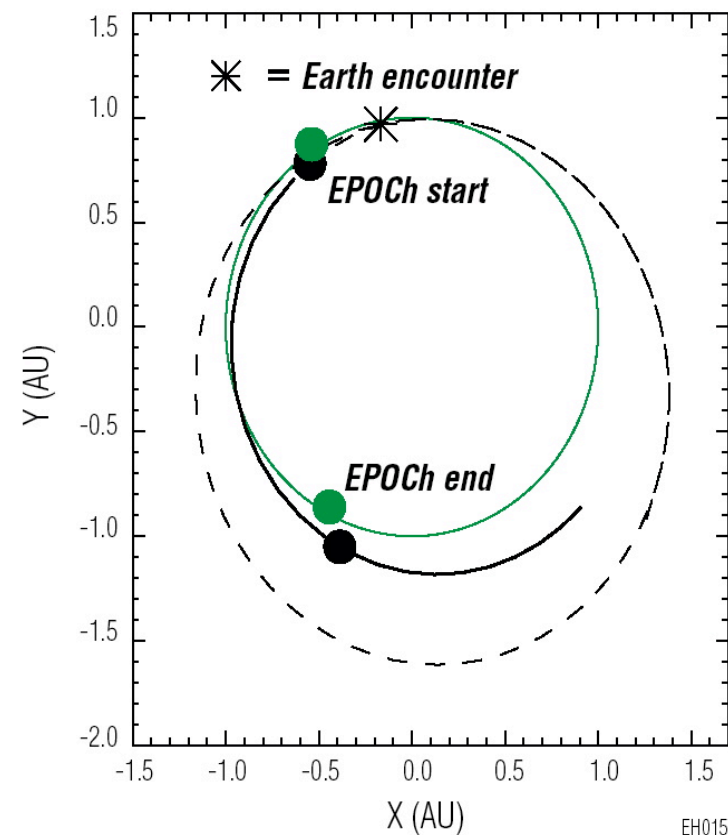
rotational light curves

inversion mapping

calibrated astronomical colors

model-independent spectroscopy

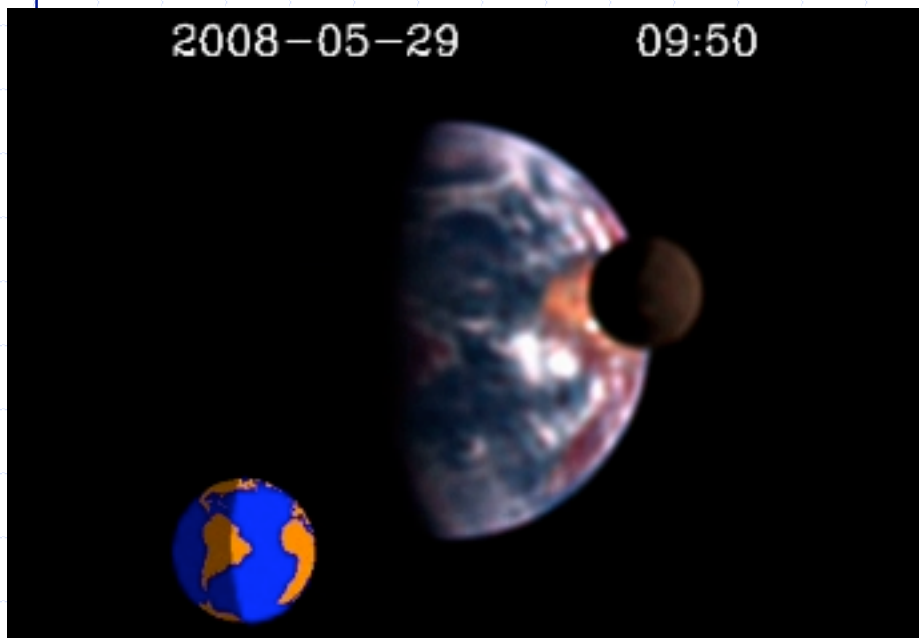
validation of the VPL



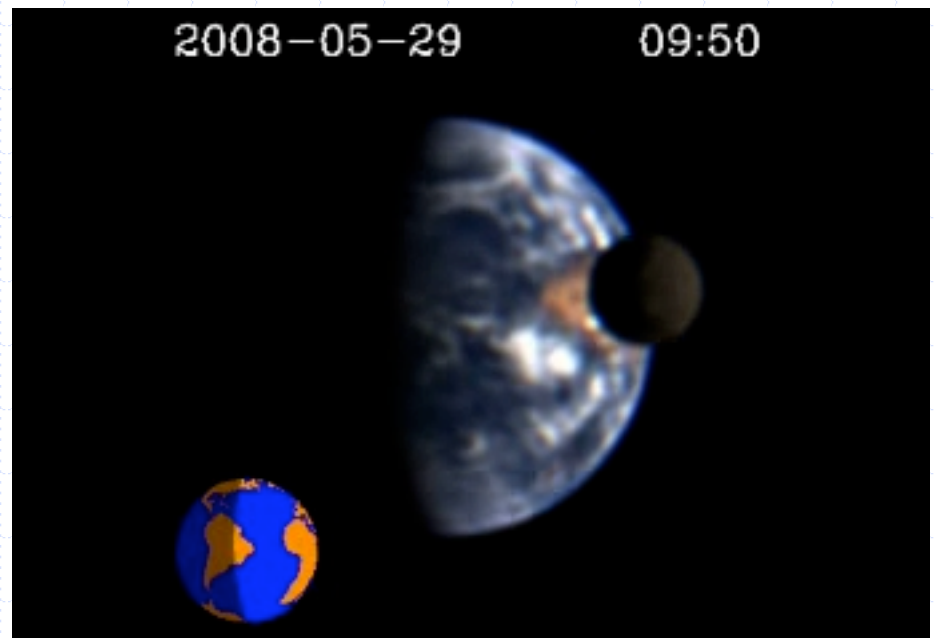
IR-green-blue vs. Red-green-blue

“let me be very clear: the following is just
about the coolest thing I have ever seen”
- Phil Plait

*Image deconvolutions
by Don Lindler (GSFC)*



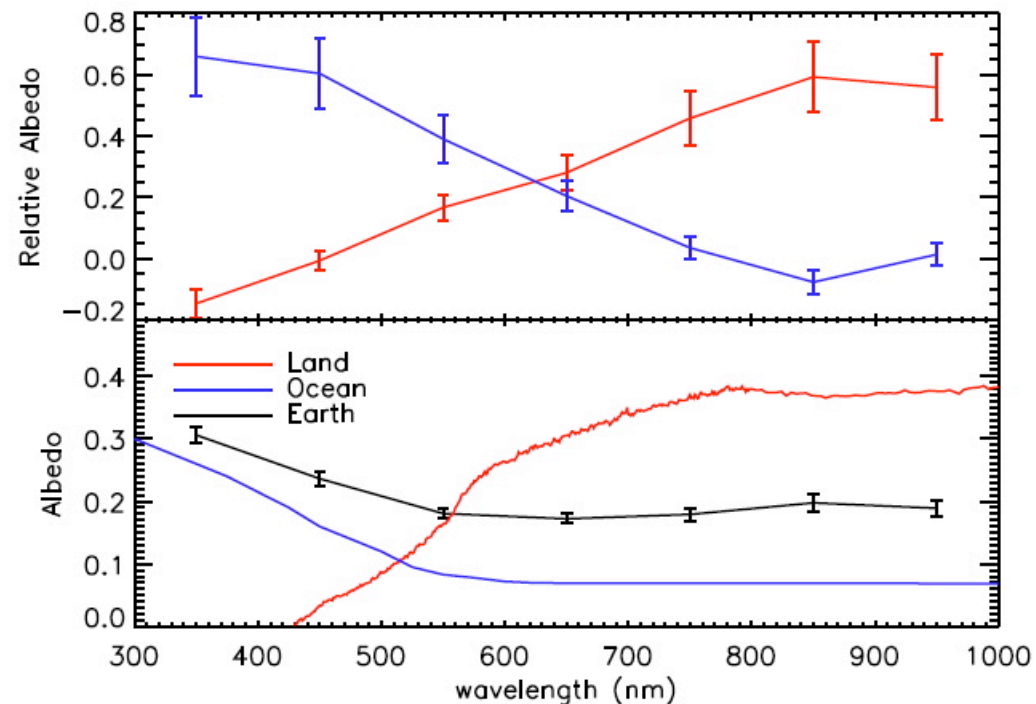
IR-green-blue
(still frame)



Red-green-blue
(still frame)

Inversion Mapping of Earth

- Sum the EPOXI data spatially - Earth as single pixel
- Use PCA to infer what spectral components are present
- ...then invert the time history of those components as the Earth rotates



Alien Maps of an Ocean-Bearing World

❑ Inversion maps show oceans and continents, but with no latitude resolution

❑ TPF will be able to infer the presence of oceans on Earth-like exoplanets

Alien Maps of an Ocean-Bearing World

Nicolas B. Cowan,^{1*} Eric Agol,¹ Victoria S. Meadows,^{1†} Timothy A. Livengood,^{2,3} Drake Deming,² Michael F. A'Hearn,³ David Charbonneau,⁴ Carey M. Lisse,⁵ Tyler Robinson,^{1†} Sara Seager,⁶ Dennis D. Wellnitz³ and the EPOXI Team

